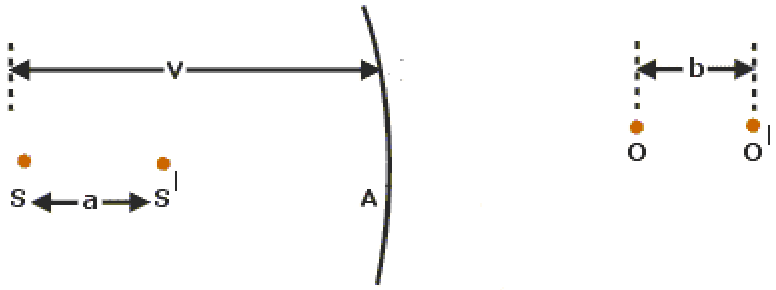
Answer on Question #61830, Physics / Other

b) i) Explain Doppler effect and obtain expression for apparent frequency when the source as well as the listener are in motion.

ii) A train moving with speed 72 km h−1 emits a whistle of frequency 600 Hz. A person is standing stationary on the platform. Calculate the frequency heard by the person if the train (i) approaches and (ii) recedes away from the listener.

Answer:

(i)



Let S and O denote the initial positions of a source of sound and an observer. For the sake of simplicity, we shall assume that the source and the observer are all moving along the positive direction.

Let the velocity of sound in still air be = v
The velocity of the source = a
The velocity of the observer = b
Let S' and O' represent the positions of the source and the observer after 1 second. Distance travelled in 1 second is nothing but the velocity.

$$SS' = a$$
$$OO' = b$$

The distance travelled by the waves relative to the source in 1 second.

$$S'A = SA - SS' = v - a$$

If f is the frequency of the waves produced by the source, then f waves are accommodated in a distance S'A.

$$Wavelength = \lambda' = \frac{S'A}{f} = \frac{v-a}{f}$$

Since the observer recedes by a distance b in 1 second, the relative velocity of the waves with respect to the observer is (v - b). Therefore, the apparent frequency is given by the number of waves of wavelength contained within the above distance.

$$f' = \frac{v-b}{\lambda'}$$

Substituting

$$f' = \left(\frac{v-b}{v-a}\right) f$$

This is the general expression for the apparent frequency of the sound when the source of sound and the observer are in motion, in the same direction.

When the listener and source moving towards each other

Now the velocity of the observer is opposite to the velocity of sound, while that of the source is the same as that of sound. 'b' is to be replaced by -b in equation

$$f' = \left(\frac{v+b}{v-a}\right) f$$

When the listener and source moving away from each other

Considering the direction of the velocity of sound reaching the observer as positive, a is negative and b is positive. Then

$$f' = \left(\frac{v-b}{v+a}\right) f$$

The apparent frequency is less than the actual frequency.

(ii) b=0

(i)

Source moving towards a stationary observer

Putting b = 0 in main equation, we get

$$f' = \left(\frac{v}{v-a}\right) f$$

The apparent frequency will be greater than the actual frequency.

v = 340 m/s,

a = 72 km/h = 20 m/s,

f = 600 Hz,

$$f' = \left(\frac{340}{340-20}\right) \cdot 600 = 637.5\ Hz$$

(ii)

Source moving away from a stationary observer

Putting -a in the place of a and b = 0 in main equation, we get

$$f' = \left(\frac{v}{v+a}\right) f$$

The apparent frequency will be lesser than the actual frequency.

v = 340 m/s,

a = 72 km/h = 20 m/s,

f = 600 Hz,

$$f' = \left(\frac{340}{340+20}\right) \cdot 600 = 566.7\ Hz$$